Having laid theſe Accounts before you, permit me the Honour to be,

SIR,

Your moſt obedient humble Servant,

H. Baker.

Catharine Street, June 18. 1750.

XVIII. *A Deſcription of a* Mariner's Compaſs *contrived by* Gowin Knight, *M.B. F.R.S.*

Read July 5. 1750.

THE Diſcovery of the Mariners Compaſs has probably been of more general and important Uſe to human Society, than the Invention of any one Inſtrument whatſoever: And yet ſo far have they been from ſtudying the Improvement of it, that there would be no Abſurdity in ſuppoſing that the firſt which was made might be as much ſuperior to thoſe in common Uſe now, as the moſt improved Inſtrument we have is ſuperior to its firſt Contrivance.

The Compaſs which appeared before this *Society* laſt Year, on account of its being render'd uſeleſs by Lightning *, was what afforded me the firſt Idea of their Imperfections, ſome of which I then enumerated; but others have ſince occurred to me, ariſing from the Structure of the Needle, which I had not ſufficiently conſidered at that time. It was then obſerved, that almoſt all the Compaſſes on board our Merchant-

* See theſe *Tranſactions*, N°. 492, *p.* 111.

Merchant-Ships had their Needles formed of two Pieces of ſteel Wire; each of which was bent in the middle, ſo as to make an obtuſe Angle; and their Ends, being applied together, make an acute one; ſo that the Whole repreſents the Form of a Lozenge; in the Centre of which, and of the Card, is placed the braſs Cap. I procured twenty Cards, with Needles of this kind fixed to them; and after touching them with a Pair of large Bars, I tried each of them, with the ſame Cup and Pin, by drawing them aſide 90 Degrees from the true Point, and then ſeeing where they would reſt. I found them all to vary more or leſs, either to the Eaſt or Weſt; and ſome of them as far as 8 Degrees. Few of them came to the ſame Degree twice together; and when they did, that was never the true Point. In ſhort, they not only varied from the true Direction, but from one another, and from themſelves. I then tried, by drawing them gently aſide, how far I could make them ſtand from the true Point, without returning; and found they might frequently be made to do it at the Diſtance of a whole Point on either Side. One of them, which generally varied 6 or 7 Degrees to the Eaſt, being drawn the ſame Way, would ſtand at 16 Degrees.

All theſe Irregularities are owing to the Structure of the Needle: For the Wires, of which it is compoſed, are only hardened at the Ends; and that is done by making the Ends red hot, and quenching them in Water: If all theſe Ends are not equally hard, or if one End be hardened higher up than the other, when they come to be put together, in fixing them to the Card, that End which is hardeſt, will deſtroy much

much of the Virtue of the other; by which means the hardeſt End will have moſt Power in directing the Card, and muſt conſequently make it vary towards its own Direction. If you retouch theſe Wires when fixed to the Card, the Error will ſtill remain; for that Wire which is beſt hardened will always become the ſtrongeſt. Conſidering how uncertain this Method of hardening the Ends of the Wires muſt be, it is a great Chance if they ſhould once in an hundred times be equally and uniformly hard: And unleſs they are, the Card to which they are fixed muſt neceſſarily vary.

The Wires being diſpoſed in the Form of a Lozenge, is the Reaſon why theſe Cards had ſo little Force, that they might be made to ſtand at the Diſtance of ſeveral Degrees, on either Side the Point from whence they were drawn. For all magnetical Bodies receive an additional Strength, by being placed in the Direction of the Earth's Magnetiſm, and act proportionably leſs vigorouſly when turned out of it. Wherefore, when theſe kind of Needles are drawn aſide from their true Point, two of the parallel Sides of the Lozenge will conſpire more directly than before with the Earth's Magnetiſm; and the other two will be leſs in that Direction: By which means the two firſt Sides will very much impede its Return; and the two latter will have that Impediment to overcome, as well as the Friction, by their own Force alone.

The Needles that are uſed on board the Men of War, and ſome of the larger trading Ships, are made of one Piece of Steel, of a Spring Temper, and are broad towards the Ends, but tapering to-

wards the Middle, where a Hole is made to receive the Cap. At the Ends they terminate in an Angle greater or leſs, according to the Skill or Fancy of the Workman. Now, tho' the worſt of theſe are infinitely preferable to thoſe of Wire, yet the beſt of them are far from being perfect. Every Needle of this Form has 6 Poles inſtead of two. There is one at each End, two where it becomes tapering, and two at the Hole in the Middle. This is owing to their Shape; for the middle Part being very ſlender, it has not Subſtance enough to conduct the magnetic Stream quite through from one End to the other. All theſe Poles appear very diſtinctly, when examined with a Glaſs that is ſprinkled over with magnetic Sand. Nevertheleſs this Circumſtance does not hinder the Needle from pointing true; but as it has leſs Force to move the Card, than when the magnetic Stream moves in large Curves from one End to the other, it is certainly an Imperfection.

I examined an hard Needle of this ſort, whoſe Ends were very broad, and terminated in an acute Angle; and obſerved, that, tho' its Motion was very free and vigorous, yet I could make it ſtand one Degree on either Side the true Point; and being at a Loſs to account for it, I tried what Appearance it would make under a Glaſs with magnetic Sand, and diſcover'd that the magnetic Stream came out of the Sides, which formed the acute Angle at the Ends, in Lines that were almoſt perpendicular to thoſe Sides, and then was bent round to go to the other Pole: From whence I concluded, that when the Needle was drawn a little from the true Point, the Stream, which came out of one of theſe Sides, would

would be more in the Direction of the Earth's Magnetiſm than before; on which account it would act ſtronger in retaining the Needle in that Situation, than the Stream of the other Side in reſtoring it; eſpecially as that Stream would be now weaker, on account of its being turned out of the magnetical Line, and would have the Friction betwixt the Cap and Pin to overcome at the ſame time.

I tried two other Needles, whoſe Ends were formed into Angles very obtuſe, and could not find that they were liable to the ſame Objection.

Two Needles, that were quite ſtrait, and ſquare at the Ends, were found to have only two Poles; but about the Hole in the Middle the Curves were a little confuſed. Theſe always came exactly to the ſame Point, after vibrating a long time; and if drawn never ſo little on one Side, would return to it again without any ſenſible Difference. We may therefore conclude, that a regular Parallelopiped is the beſt Shape for a Needle, as well as the ſimpleſt; with the Holes for the Caps as ſmall as can well be contrived; or if it can be made to anſwer the Purpoſe without any Hole at all, it will be ſtill more perfect.

Yet the common Shape has one Advantage which this has not: For, being made broad at the Ends, and ſlender in the Middle, its Weight is removed as far as poſſible from the Centre: On which account, if it once points true, the Friction at the Centre cannot ſo eaſily put it in Motion; and its Vibrations, when in Motion, will be ſlower; ſo that their Limits may be more nicely obſerved, and the middle Point betwixt them is that where it would

ſtand, if at reſt. Being unwilling to part with theſe Advantages, I contrived a light Circle of Braſs, of the ſame Diameter with the Card, which will ſupply a Weight acting at the greateſt Diſtance from the Centre of Motion, and alſo ſerve to ſupport the Card; which may now be made of thin Paper, without any thing to ſtiffen it. So that the extraordinary Weight of the braſs Ring is compenſated in a great meaſure by the Lightneſs of the Card. This Ring is of Service in another reſpect; for, being fixed below the Card, and the Needle above it, the Centre of Gravity is placed low enough to admit of the Cap being put under the Needle; whereby the Hole in the Needle becomes unneceſſary; and the latter being placed above the Card, renders it eaſier to be touched with a Pair of Bars.

Having thus completed the Needle and Card to my Satisfaction, what chiefly remains, is, to contrive ſuch a Cap and Point as will have the leaſt Friction, and be moſt likely to continue in a State of Perfection. The Caps in Uſe are either of Braſs, a mixed Metal, like that of a reflecting Teleſcope, Cryſtal, or Agate. The two firſt will only admit of braſs Points, and the latter are rather too expenſive for common Uſe. Wherefore I bethought myſelf of trying glaſs Caps: I had three of them made by a Glaſs-blower, two of which I got poliſhed: They were all ſet in Braſs, ſo as to ſcrew into the ſame Needle, which had alſo one of Agate fitted to it. I compared them with that of Agate, by trying with each of them how many Vibrations the ſame Card and Needle would make, when drawn aſide 90 Degrees,

Degrees, on the ſame Point; which was a very ſmall ſewing Needle.

The Number of Vibrations with the Agate Cap, on the firſt Trial, were 39, then 37, then 39 again; with one of the glaſs Caps it made 23, and then 20. This Difference from the Agate Cap was ſo great, that I concluded the Point muſt be damaged, and therefore choſe a finer; on which the ſame glaſs Cap made 41 Vibrations; then 43; and another glaſs Cap made 47, and the next time 43. But the Agate Cap with this Point made 51, 57, and 58 Vibrations. The unpoliſhed glaſs Cap performed much the ſame with the others. I had two of them poliſhed again by Mr. *Smeaton*; and in Company with him repeated the ſame Experiments; but with no better Succeſs. The Agate Cap made always many more Vibrations than the glaſs one; and generally with the latter the Number diminiſhed by repeated Trials; whereas with the Agate Cap it uſually increaſed.

Theſe Experiments made me lay aſide the Thoughts of glaſs Caps, and put me upon thinking how Agate ones might be made with as little Expence as poſſible.

With this View I got a Cap turned of Ivory, in ſuch a manner as to receive a ſmall Bit of Agate at the Top. This being ground concave, and poliſhed on that Side, where it formed the *Apex* of the hollow Cone in the Cap, was capable of anſwering the Purpoſe as well as if the Whole had been Agate, and was much lighter. Theſe Caps may be made cheap enough for common Uſe; and, if good at firſt, cannot eaſily be impaired.

For

For a Point, I choſe a common ſewing Needle, and contrived to fix it in ſuch a manner as to be taken out with the greateſt Eaſe, and replaced by another, if neceſſary; by which means an excellent Point may be always had with little Trouble or Expence. Common Needles, when well temper'd, have all the Qualifications that can be deſired for the Purpoſe intended. The ſmalleſt are ſtrong enough to bear the Weight of a Card; and are neither ſo ſoft as to be liable to bend, nor ſo hard and brittle as to break; and they are generally better pointed than any that a common Workman could pretend to make *extempore*.

Thus we have gone through all the Parts that are eſſential to a Mariner's Compaſs; and endeavoured to put them upon ſuch a Footing, as to leave as little Room as poſſible for Error in their firſt Conſtruction, or Failure in the long continued Uſe of them.

This, which I have now the Honour to exhibit to the *Society*, was made by Mr. *Smeaton*, a Gentleman whoſe uncommon Skill in the Theory and Practice of Mechanics has enabled him to execute whatever I propoſed in ſuch a manner as always to exceed my Expectations: And not only ſo, but he has added a conſiderable Improvement of his own. By a very ſimple Contrivance he has made the ſame Inſtrument capable of ſerving the Purpoſes of an Azimuth and Amplitude-Compaſs; and that in a manner much preferable to any thing hitherto contrived; the Deſcription and Uſe of which he has drawn up himſelf, for the Peruſal of the *Society*.

XIX.